



# Standard Operating Guidelines

SOG #: T106 – Particulate Monitoring Guide for Fires

Created: September 11, 2015, Updated: February 23, 2017, Version 1.0

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## Summary

- This guide is intended to be used for monitoring particulates released from fires. Effects from other potential pollutants and products of combustion are not addressed in this document. [Refer to EPA Emergency Response Air Monitoring Guidance Tables, 2012 Edition 3<sup>a</sup>](#) for guidance on other pollutants.
- PM<sub>2.5</sub> is the preferred metric for fire response particulate monitoring.
- The DataRAM 4 and the DustTrak DRX 8533EP are the standard monitoring instrument for measuring particulate concentrations.
- The E-BAM, available from ERT, is the alternate monitoring instrument when accuracy is a critical factor.
- Instrument accessories may be needed to offset weather variables and provide power during extended monitoring periods.
- Establish monitoring sites downwind of the hot zone and immediately upwind. Monitoring may also be recommended in the hot zone if there is a health risk to response workers.
- Use Table 1 to select the appropriate response action. Community action levels apply to everyone in neighboring areas affected by smoke. Worker action levels apply to response workers at the site.

## Introduction

Fire presents a multitude of health and safety hazards as a result of effects on air quality. Smoke is the most visible air pollutant and is composed of Carbon Monoxide (CO), Carbon Dioxide (CO<sub>2</sub>), Water Vapor, Particulate Matter (PM), hydrocarbons, organic chemicals, Nitric Oxides (NO<sub>x</sub>), and minerals. Smoke can disperse quickly and may present significant health risks for nearby communities. Variables that impact dispersion include wind, temperature, moisture, and topography. Air monitoring guidance for these and other products of combustion are presented in the [EPA Emergency Response Air Monitoring Guidance Tables<sup>a</sup>](#).

PM consists of solid and liquid particles suspended in air. PM can readily enter the body through inhalation and can cause both acute and chronic health effects. Particulates will be present in all smoke resulting from a fire, regardless of the fuel source; however, different types of fuels will produce different sizes and concentrations of PM. Heat is also a factor which can effect particulate concentrations. After a fire has been suppressed, particulate concentrations can be higher during the smoldering phase because of less-complete combustion<sup>b</sup>.

Most particulates in smoke are between 0.4 - 0.7 micrometers (µm) which is considered respirable. Particulates are typically classified as PM<sub>10</sub> or PM<sub>2.5</sub> which refers to the particulate size.

- PM<sub>10</sub> is defined as “course” particles measuring 10 µm or less in diameter.
- PM<sub>2.5</sub> is defined as “fine” particles with a diameter equal to or less than 2.5 µm.

It is recommended that monitoring efforts focus on measuring PM<sub>2.5</sub> during emergency fire responses. The California Air Resource Board states that most smoke particulates are between 0.4 – 0.7 µm, and concludes PM<sub>2.5</sub> would be a more practical monitoring parameter to use<sup>b</sup>. In 2007, Naeher et al. also indicated that PM<sub>2.5</sub> was the more suitable particulate monitoring metric<sup>c</sup>. Further, the EPA Air Quality Index (AQI) uses PM<sub>2.5</sub> in the health rating guide, also suggesting that PM<sub>2.5</sub> is the more appropriate standard when looking at the health hazards of particulates.

## Links to Additional Information:

- [Graph of particle size distribution of atmospheric particles](#)
- [Graph of particle size from particulate emissions](#)
- [Emission Study with graph of particle size distribution](#)



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## Air Quality Thresholds, Actions and Recommendations

Evacuation and/or protect-in-place procedures should be recommended for areas downwind of or in the visible smoke cloud.

Once instrument readings become available, the concentrations may be an indication of potential exposure. Table 1 (for PM<sub>2.5</sub>) and Table 2 (for PM<sub>10</sub>) lists the threshold levels for different concentrations and the recommended actions that should be taken to prevent harm to community members and workers/responders at the response site. These actions may include communication with community members, evacuations, and medical monitoring. Consider consulting ATSDR to assist with generating public health statements, factsheets and possible development of a medical monitoring plan.

Criteria listed in the Protective Action Criteria (PAC) were assessed, but the values for particulates were much higher than those used in the AQI<sup>d</sup>. Because of this, the PAC values are not the preferred metric for response action guidance.

Odors and visible air opacity may trigger complaints and concerns in affected areas. Conditions and individual sensitivities can play a significant role in determining the point at which smoke becomes noticeable. If such concerns are presented, monitoring instrument results and Table 1 (for PM<sub>2.5</sub>) and Table 2 (for PM<sub>10</sub>) recommendations should be used to guide response actions.



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**TABLE 1: Threshold Levels and Recommended Response Actions for PM<sub>2.5</sub>**

PM <sub>2.5</sub> Threshold Levels (µg/m <sup>3</sup> )		Level of Health Concern	Meaning	Action
1 Hr. Avg. <sup>1</sup>	24 Hr. Avg. <sup>1</sup>			
COMMUNITY ACTION LEVELS				
0.0 – 40.0	0.0 – 12.0	Good	Air quality is considered satisfactory, and air pollution poses little or no risk	Implement communication plan <sup>2</sup> .
40.1 – 80.0	12.1 - 35.4	Moderate	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive <sup>3</sup> to air pollution.	Issue public announcement about health effects <sup>2</sup> . Stay out of areas with visible smoke.
80.1 – 175.0	35.5 - 55.4	Unhealthy for Sensitive Groups	Members of sensitive groups may experience health effects. The general public is not likely to be affected.	Recommend evacuation or shelter-in-place for sensitive populations <sup>2,4</sup> .
175.1 – 300.0	55.5 - 150.4	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.	Consider closing schools and cancelling outdoor events. Recommend shelter-in-place for affected neighborhoods.
300.1 - 500.0	150.5 - 250.4	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected.	Consider closing schools and cancel all outdoor events. Recommend shelter-in-place and/or evacuation for affected neighborhoods.
> 500.0	> 250.5	Hazardous	Health alert: everyone may experience more serious health effects	Recommend closing schools & cancel outdoor events. Recommend closing workplaces and evacuating affected neighborhood.
Source	Particulates not otherwise regulated/specified (µg/m <sup>3</sup> )		Meaning	Action
	8 Hr. Avg.			
WORKER ACTION LEVELS				
OSHA PEL	15,000 (total dust) 5,000 (respirable fraction - <10µm)		Safe with use of level D PPE up to this level.	Levels above the 8 hour TWA require the use of level C PPE (use P100 particulate filter). See <a href="#">ERRB P100 – PPE Guidelines for Specific Activities/Tasks and P102 - Respiratory Protection Equipment Selection</a> .
ACGIH TLV	10,000 (inhalable fraction - <100µm) 3,000 (respirable fraction - <10µm)		Safe with use of level D PPE up to this level.	Consider implementing industrial hygiene measures and/or using level C PPE.

<sup>1</sup> Threshold values taken from original EPA AQI online calculator found at [http://airnow.gov/index.cfm?action=resources.aqi\\_conc\\_calc](http://airnow.gov/index.cfm?action=resources.aqi_conc_calc) for PM<sub>2.5</sub> (24 hour) and Idaho Department of Environmental Quality AQI for PM<sub>2.5</sub> (1 hour) taken from <http://app.airsis.com/usfs/aqi.asp>.

<sup>2</sup> Recommendations from EPA Air Now web site. See Reference E.

<sup>3</sup> People who are unusually sensitive to air pollution are a subset of Sensitive Individuals. Unusually sensitive to air pollution can be defined as the very young, the elderly, pregnant women, and the immunocompromised.

<sup>4</sup> Sensitive individuals defined as people with lung disease, older adults and children who are at a greater risk from exposure to ozone; and persons with heart and lung disease, older adults and children who are at greater risk from the presence of particles in the air. See Reference E.



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**TABLE 2: Threshold Levels and Recommended Response Actions for PM<sub>10</sub>**

PM <sub>10</sub> Threshold Levels (µg/m <sup>3</sup> ) <sup>1</sup>			
24 Hr. Avg.	Level of Health Concern	Meaning	Action
<b>COMMUNITY ACTION LEVELS</b>			
0.0 – 12.0	Good	None	Implement communication plan <sup>2</sup> .
12.1 – 55.0	Moderate	Unusually sensitive <sup>3</sup> people should consider reducing prolonged or heavy exertion.	Issue public announcement about health effects <sup>4</sup> .
55.1 – 155.0	Unhealthy for Sensitive Groups	Increasing likelihood of respiratory symptoms and aggravation of lung disease, such as asthma.	Recommend evacuation or shelter-in-place for sensitive populations <sup>2,4</sup> .
155.1 – 255.0	Unhealthy	Increased respiratory symptoms and aggravation of lung disease, such as asthma; possible respiratory effects in general population.	Consider closing schools and cancelling outdoor events. Recommend shelter-in-place for affected neighborhoods.
255.1-355.0	Very Unhealthy	Significant increase in respiratory symptoms and aggravation of lung disease, such as asthma; increasing likelihood of respiratory effects in general population.	Consider closing schools and cancel all outdoor events. Recommend shelter-in-place and/or evacuation for affected neighborhoods.
355.1-425.0	Hazardous	Serious risk of respiratory symptoms and aggravation of lung disease, such as asthma; respiratory effects likely in general population.	Recommend closing schools & cancel outdoor events. Recommend closing workplaces and evacuating affected neighborhood.

<sup>1</sup> Threshold values taken from EPA AQI online calculator found at [http://airnow.gov/index.cfm?action=resources.aqi\\_conc\\_calc](http://airnow.gov/index.cfm?action=resources.aqi_conc_calc)

<sup>2</sup> Recommendations from EPA Air Now web site. See Reference E.

<sup>3</sup> People who are unusually sensitive to air pollution are a subset of Sensitive Individuals. Unusually sensitive to air pollution can be defined as the very young, the elderly, pregnant women, and the immunocompromised.

<sup>4</sup> Sensitive individuals defined as people with lung disease, older adults and children who are at a greater risk from exposure to ozone; and persons with heart and lung disease, older adults and children who are at greater risk from the presence of particles in the air. See Reference E.



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## Monitoring Instruments and Methods

Region IV Emergency Response, Removal and Prevention Branch (ERRPB) currently uses the DataRAM 4 and the DustTrak DRX 8533EP for particulate monitoring.

The DustTrak DRX 8533EP was added to the Branch inventory in February 2017. The DustTrak uses light scattering measurement similar to the DataRAM 4 but has the ability to both size and mass fractions simultaneously. The unit concurrently provides PM<sub>10</sub>, PM<sub>4</sub>, PM<sub>2.5</sub>, PM<sub>1</sub> and Total particulate data without having to change the impactor head. The customized units the Branch maintains have external pumps, and a built in/automatic heater unit that is preset to keep the moisture level below 40%.

The DataRAM 4 has advantages such as portability, an internal power supply, and a large detection range. One of the drawbacks of the DataRAM 4 is that mass concentrations tend to be over-estimated. United States Forestry Service (USFS) studies have shown that the DataRAM 4 estimations are on average 144% higher than actual concentrations<sup>f</sup>. Because of this, the USFS recommends applying a correction factor of 0.39 to instrument readings<sup>f</sup>. The DataRAM 4 is the preferred instrument when portability is important and/or if very high concentrations are expected (i.e. at source).

The E-BAM monitor is available through EPA Environmental Response Team (ERT), and is considered to be the most accurate monitoring instrument available. Some of the drawbacks include reduced portability (heavier, awkward shape), narrow detection range, and it requires an auxiliary power source. The E-BAM is the preferred instrument when accuracy is a critical factor and high concentrations are not expected (i.e. better for measuring fugitive dust concentrations on metals removal sites).

Use of monitoring instruments can also be affected by available resources, weather, and environmental conditions. Accessories and adapters may be required to offset the effects of these variables.

- **Heater:** A temperature conditioning heater must be used if humidity is > 40%. Without a heater in these conditions, measurements may be biased towards higher readings. Refer to instrument manual for further instruction. These are available for most particulate monitoring instruments.
- **Power Generation:** Most instruments will run for 15-24 hours on a full battery charge. A generator, solar panel, or auxiliary battery system will likely be needed for equipment without a built-in power supply or for continuous monitoring > 15 hours.
- **GFCI:** If a power generation system is used, a power strip/surge protector should be used to accommodate other accessories and monitoring equipment. This will also prevent possible electrical damage to expensive equipment.
- **Impactor:** The DataRAM and DustTrak are used with an impactor attachment which connects to the air intake. This functions as a pre-collector to help offset some of the effects of wind and precipitation. It should be utilized at all times.

**TABLE 3. Instruments Available for an EPA Response**

Criteria	DataRAM 4	E-BAM	DUSTTRAK DRX 8533EP
Accuracy (% above actual) <sup>1</sup>	144%	1%	Not determined
Detection Range (µg/m <sup>3</sup> ) <sup>2</sup>	0.1 - 400,000	0.1 - 65,000	0.1 - 400,000
Weight (lbs) <sub>2</sub>	13	28 (without battery)	
Setup Time	15 min	15-30 min	15 min
Measurement Method	light scattering	filter tape	90° light scattering
Power Requirements	Re-chargeable internal battery. 24 hr. run time.	Requires AC power source or external DC. Solar option avail.	Dual re-chargeable batteries, 12 hour run time each.
Availability	Regional Readiness Center (6 units)	1-2 days via EPA ERT	Regional Readiness Center (3 units)

<sup>1</sup> based on results from US Forest Service 2006 study *Smoke Particulate Monitors*. See Reference F.

<sup>2</sup> taken from manufacturers specifications.



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**Table 4. Comparison of Common Particulate Monitors on the Market**

Criteria	DataRAM 4000	DataRAM 2000	E-BAM	E-Sampler	DUSTTRAK
Accuracy (% above actual) <sup>1</sup>	144%	15%	1%	13%	217%
Detection Range (µg/m <sup>3</sup> ) <sup>2</sup>	0.1 - 400,000	0.1 - 400,000	0.1 - 65,000	0.1 - 65,000	0.1 - 400,000
Weight (lbs) <sup>2</sup>	13	12	28 (without battery)	12 (without battery)	9 (device only); 38 (with enclosure)
Setup Time	15 min	15 min	15-30 min	15-30 min	Unknown
Measurement Method	light scattering	light scattering	filter tape	light scattering	90-degree light scattering
Power Requirements	Re-chargeable internal battery. 24 hr. run time.	Re-chargeable internal battery. 24 hr. run time.	Requires AC power source or external DC. Solar option	Requires AC power source or external DC. Solar option	Re-chargeable internal battery. 15-24 hr. run time.

<sup>1</sup> based on results from US Sorest Service 2006 study *Smoke Particulate Monitors*. See Reference a.

<sup>2</sup> taken from manufacturers specs

## Monitoring Locations

Monitoring for particulates should take place both at the work zone and in surrounding areas where the smoke may travel or accumulate. Consider areas between the release point and sensitive receptors. Temperature, wind, and humidity can affect where smoke travels. As the earth's surface is heated in the afternoon, the atmosphere becomes more unstable when heated air expands. This causes smoke to disperse in a more vertical pattern in the afternoon and early evening. Warm temperatures or major changes in daytime high/low temperatures will cause the smoke to rise higher than in cooler temperatures with a narrow high/low range. As the atmosphere stabilizes overnight and through the morning, smoke will disperse horizontally and settle into low-lying areas and valleys<sup>g</sup>.

Wind is a significant factor in smoke dispersion. Unstable atmospheric conditions in the afternoon also increase wind speed which increases the rate and distance of dispersion. Humidity above 80% can cause moisture to condense on smoke particles. This can create a fog type effect which slows and settles smoke. Precipitation can cause a similar effect and slow dispersion. Atmospheric inversions should be taken into consideration when determining monitoring locations and recommending evacuation or protect-in-place zones. An atmospheric inversion occurs when a layer of air that is warmer than the air below traps the surface air in place and prevents dispersion of any pollutants it contains.

Surface structures such as buildings and trees can significantly change air flow direction and cause stagnant air pockets to form. This can trap smoke in small, confined areas and create hot spots with significantly higher particulate concentrations than nearby locations. When monitoring areas which are surrounding the source consider the following:

- Downwind areas will be most impacted by smoke.
- It should be expected that particulate readings at ground level will be higher at night or in the morning than in the afternoon or early evening.

Monitoring at the work zone may be necessary to establish appropriate levels of PPE for response workers. This will also help to determine safe areas to stage response support activities where workers may not be using protective equipment.



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When choosing a monitoring site, some additional items should also be considered:

- Availability of power sources will determine what type of power generation is required. The absence of auxiliary power will require more frequent maintenance and may require additional staffing, especially if the monitoring period is > 24 hours.
- Consider security measures (i.e. locked boxes, chains, etc.) if instruments are to be sited in public areas and left unattended.
- Ensure generators or equipment from other activities which may release emissions do not interfere with monitoring stations.
- Power lines or electrical utility areas should be avoided.

## Health Effects

PM<sub>10</sub> and PM<sub>2.5</sub> are considered to be respirable. Particulates > 10 µm do not typically reach the lungs, but can irritate the eyes, nose, and throat. Although PM<sub>10</sub> is respirable, PM<sub>2.5</sub> is inhaled deeper into lung tissue due to their small size (approximately 1/30<sup>th</sup> the average width of human hair<sup>h</sup>), and thus presents a greater health hazard than larger particulates. PM between 0.1 µm and 1 µm can remain in the atmosphere for days or weeks, meaning there is a potential for long range dispersion from the source.

Smoke and particulate exposure will typically have the largest effect on the respiratory system. Irritation and coughing are common acute symptoms of exposure to particulates. Individuals subject to particulate exposure may first notice irritation of the throat, eyes, and nose. This may be followed by coughing, chest pain, and shortness of breath if exposure continues.

- Acute effects of particulate exposure include irritation of the respiratory system, coughing, and breathing difficulties.
- Chronic effects of particulate exposure include reduced lung function, asthma, lung cancer, chronic bronchitis, cardiovascular disease, premature death, and may cause birth defects<sup>e</sup>.

These symptoms can be magnified for sensitive individuals, which can include groups or individuals with pre-existing conditions (e.g.: asthma, heart disease, lung disease), children, the elderly, and pregnant women. Sensitive individuals can experience aggravation of respiratory and cardiovascular systems at lower levels which may not affect non-sensitive individuals<sup>e</sup>.

PM can also transport other pollutants which creates additional health concerns. Special consideration and precautions should be made if other pollutants are expected. ATSDR can provide assistance with generating public health statements, factsheets and possible development of a medical monitoring plan.

## Reporting

Generate air monitoring summary reports to present data to the Incident Management Team (IMT) during Command, Planning, and Tactical meetings/briefings. Air monitoring summary reports typically group instruments by location and summarize each analyte result with number of readings, number of detections, concentration range, and a time-time weighted average over the period of the report. For particulates, specifically, the air monitoring report typically classifies the reporting period based on the AQI as seen in Table 1 and Table 2.

Develop the reporting schedule around the operational periods established by the IMT, and include sufficient time to review air monitoring summary reports prior to meetings/briefings since they often become the data backing up health-based decisions (e.g. whether to modify/implement evacuation zones or how to advise schools on openings/delayed starts).





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## References

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